CADMUS

Cold Climate ASHP Evaluation

2017 Regional Cold Climate ASHP Market Transformation Workshop

Andover, MA

June 27, 2017

Evaluation Background

- 152 residences in MA and RI
- Conducted participant surveys
- Collected home attribute data
- Metered DHP systems for ~16 months during 2015 and 2016

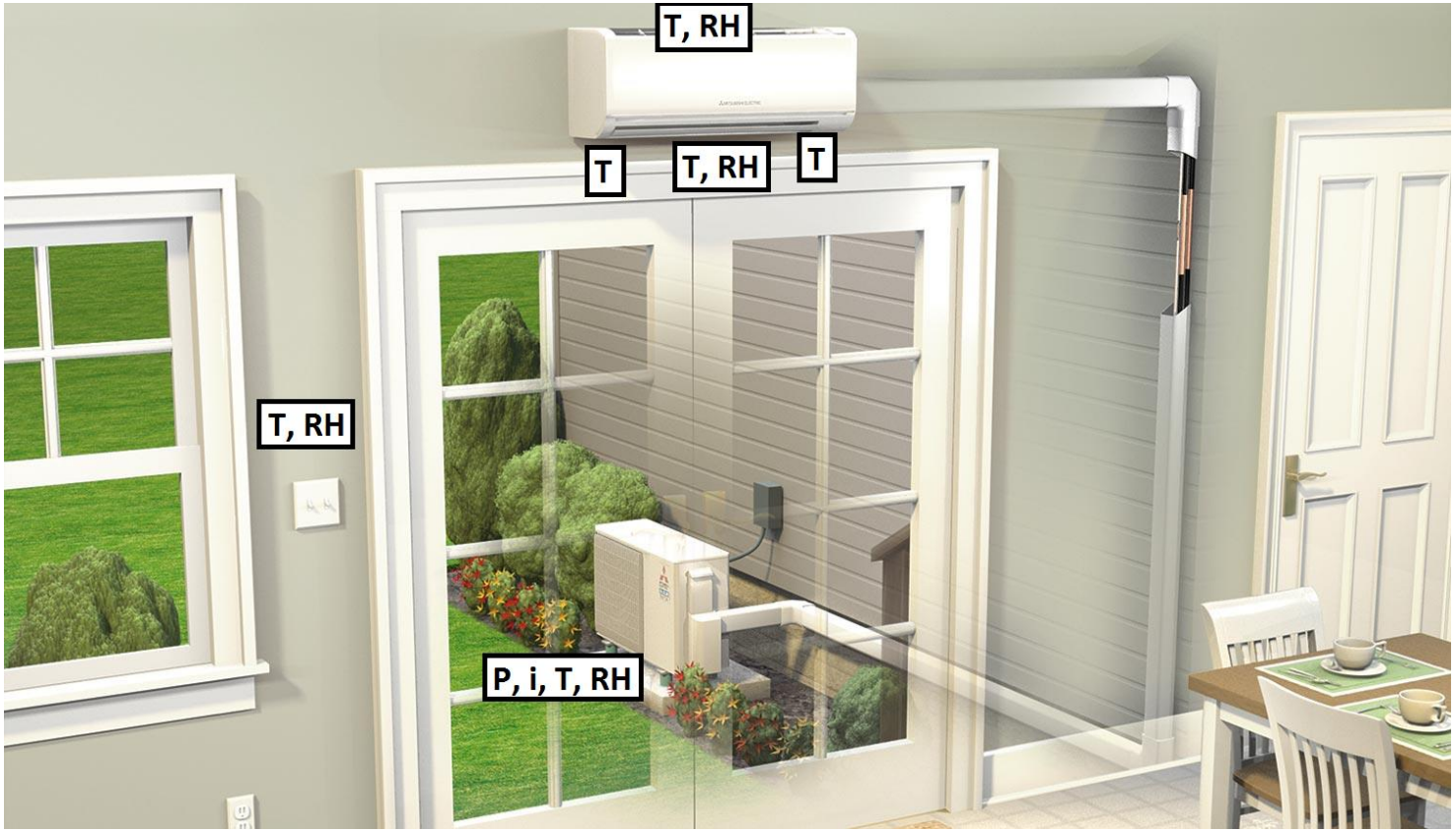
Primary Research Objectives

- Determine power and energy savings
- Compare performance of cold climate and non-cold climate systems
- Evaluate system sizing and performance



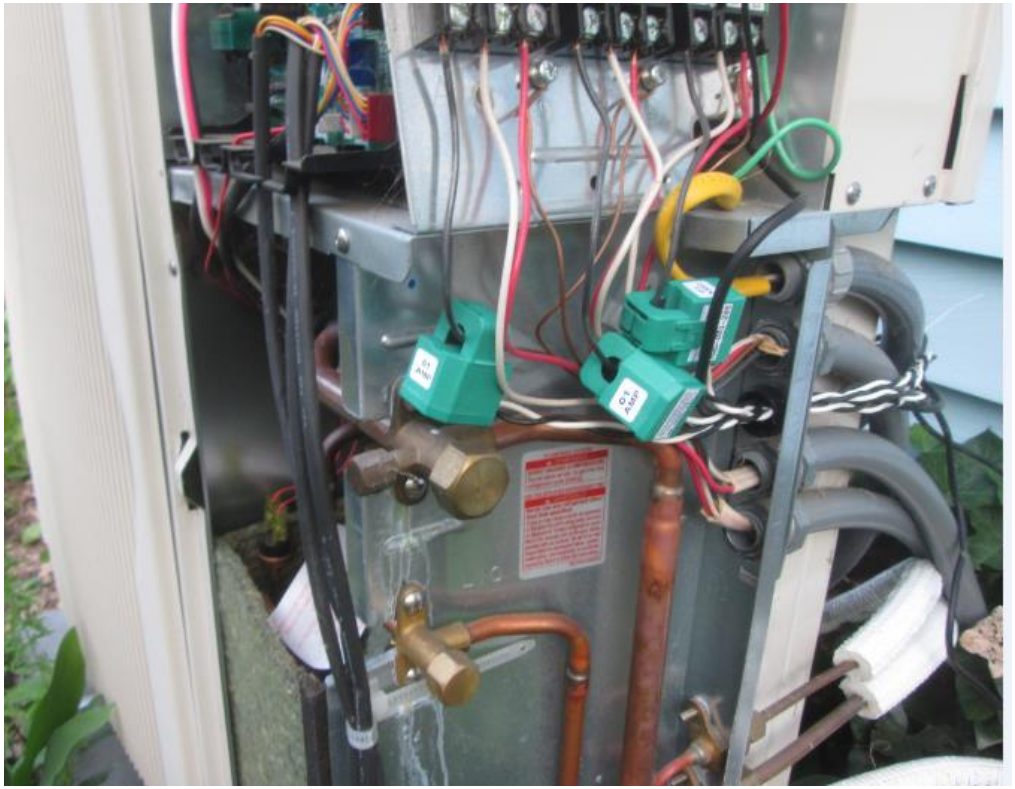

Locations of Sampled Residences

System Monitoring



Source of background image: MITSUBISHI ELECTRIC COOLING & HEATING

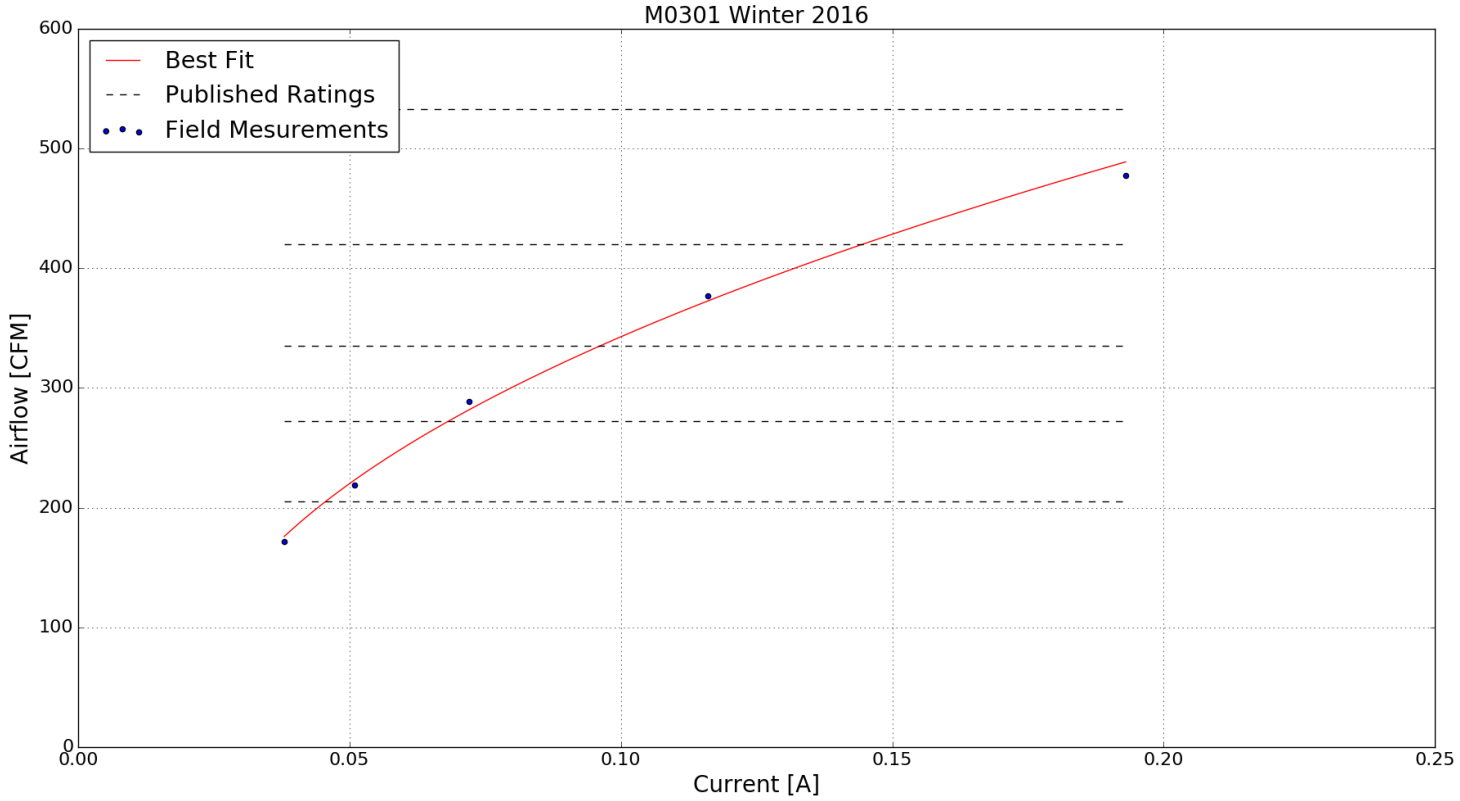
System Monitoring



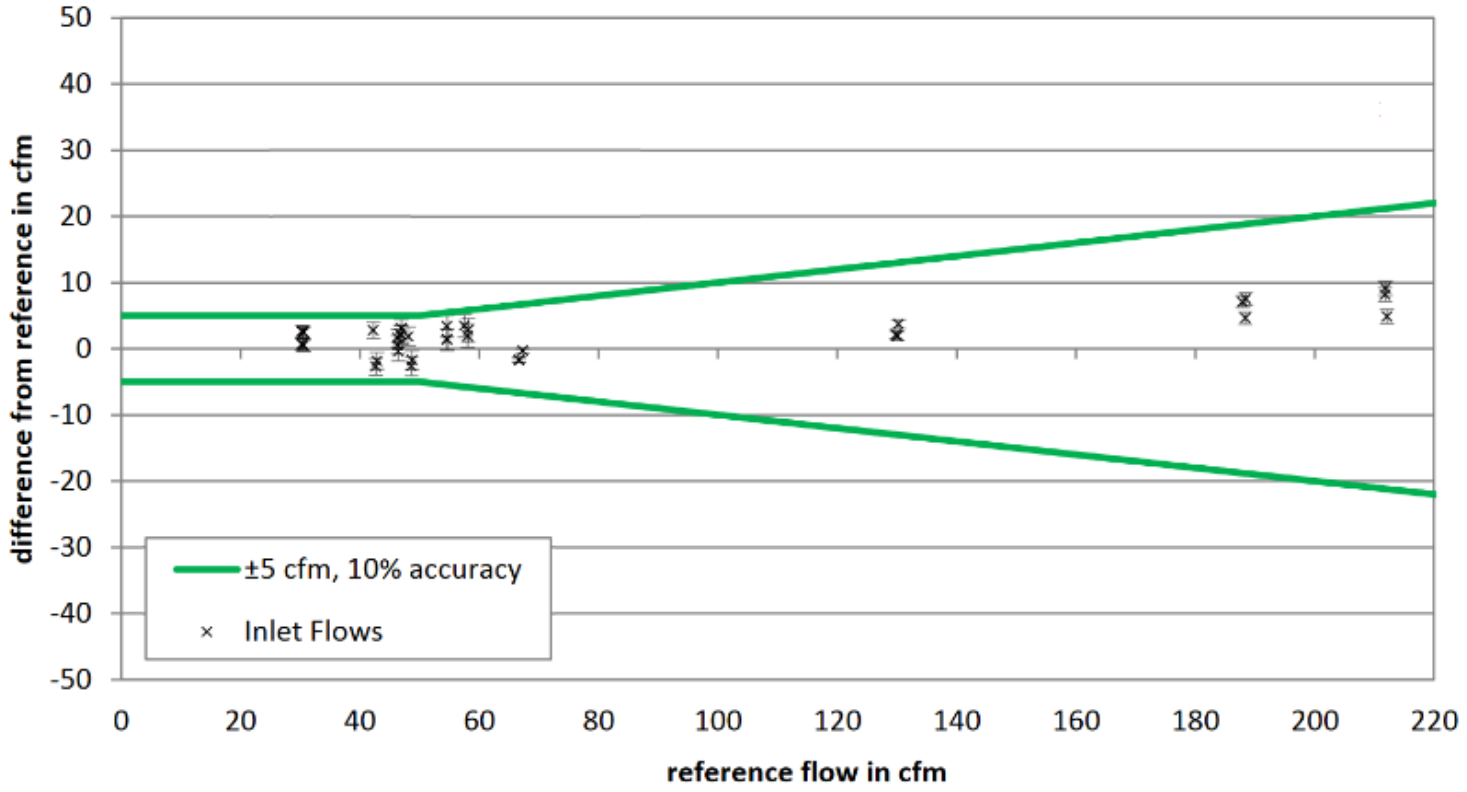
Measuring Airflow: Alnor Balometer




Correlating Airflow and Current



Measuring Airflow: Alnor Balometer Accuracy

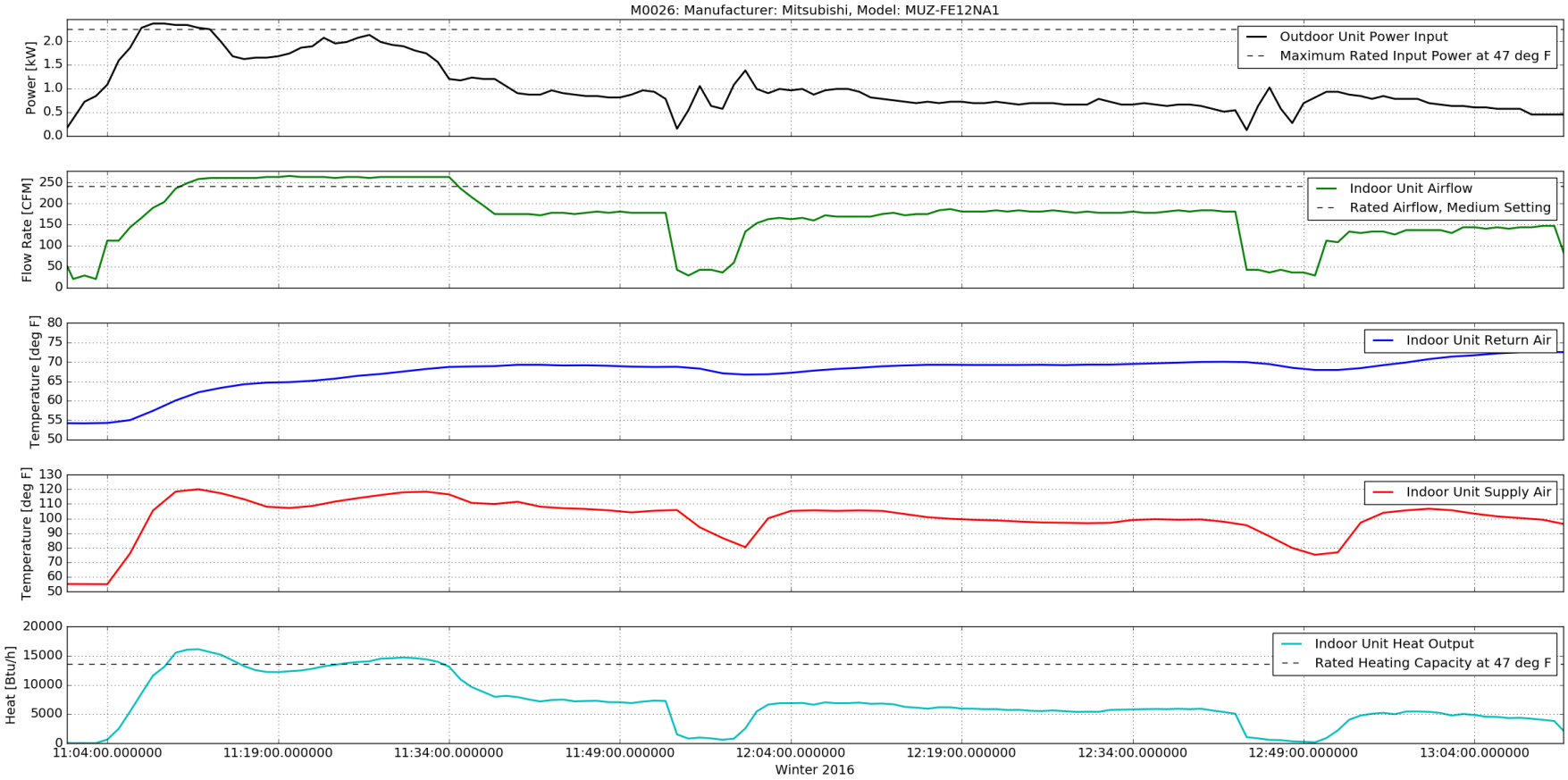


Source: LBNL-5983E Figure 14, Adapted (Stratton et al. 2012)

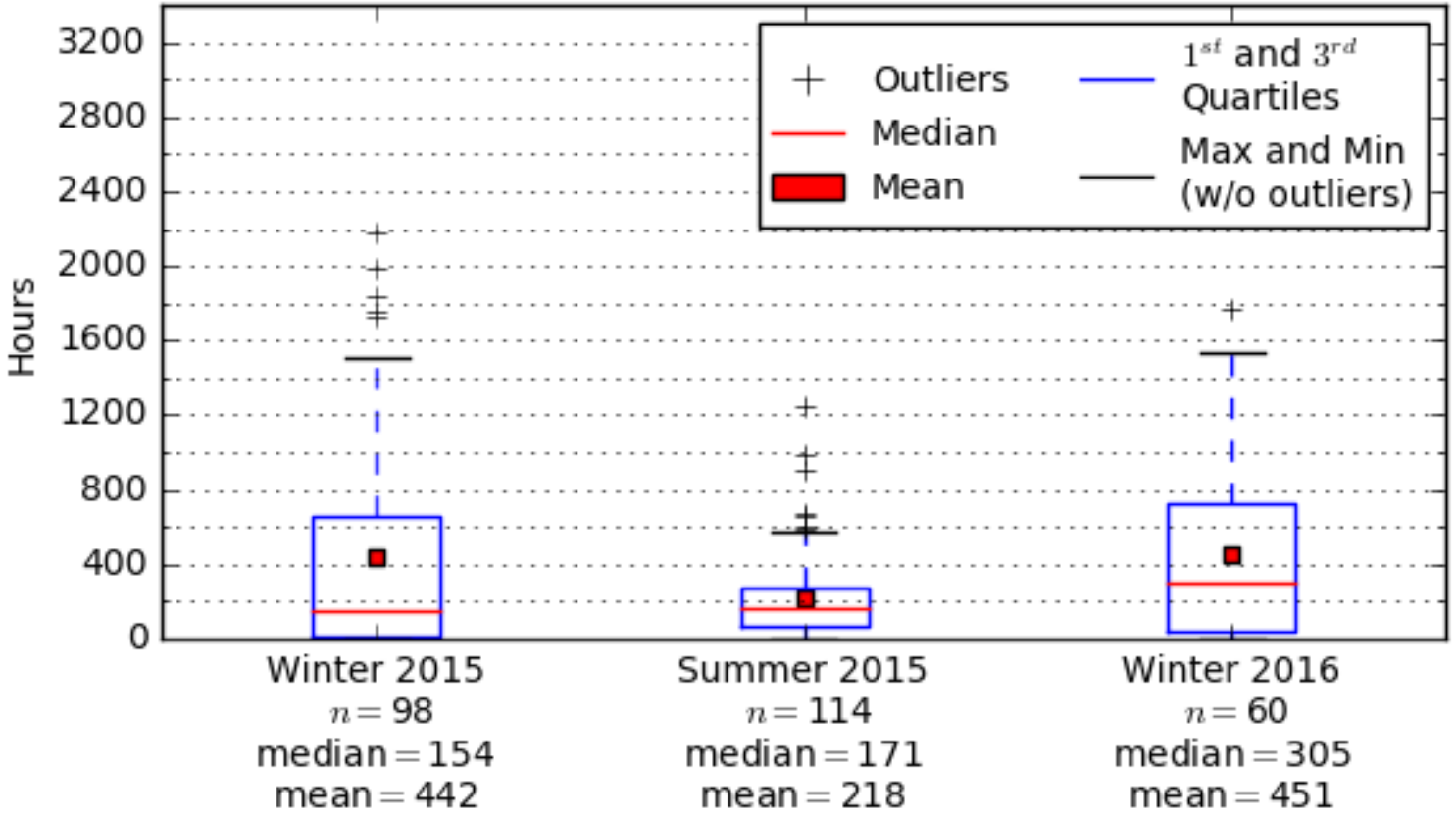
Measuring Airflow: Powered Flow Hood




Sample Data Streams



Equivalent Full Load Hours (EFLH) vs. Season



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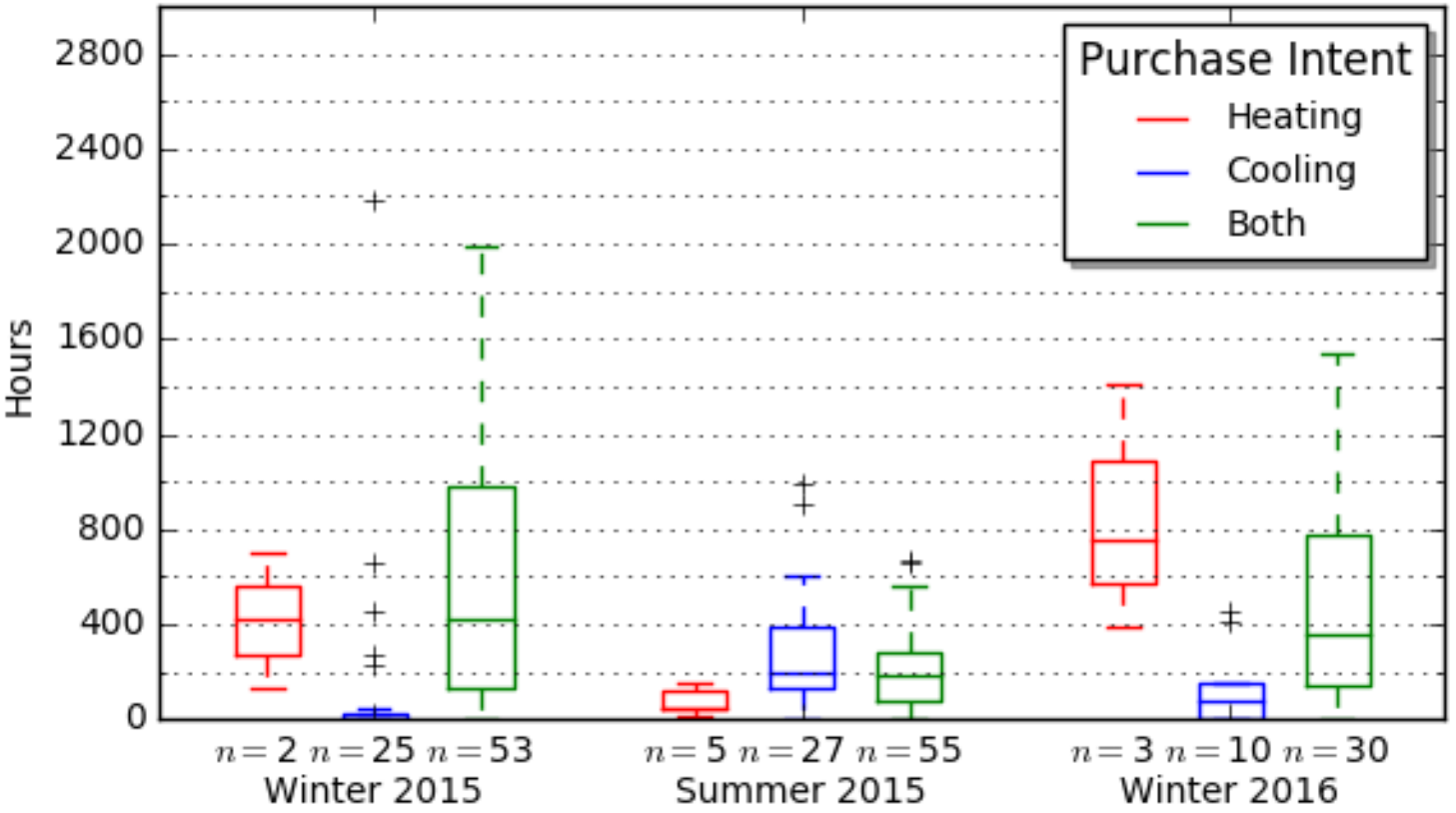


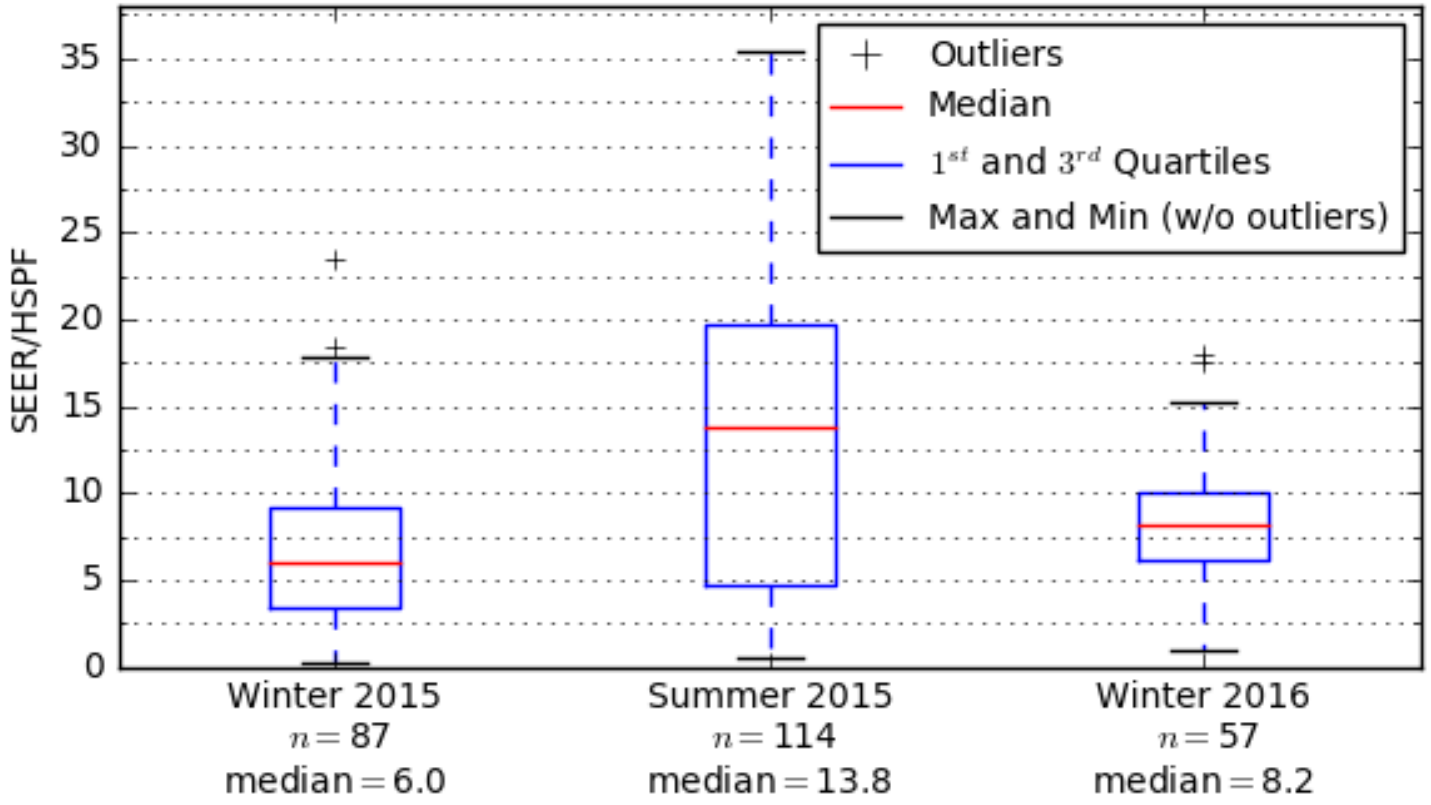
Energy Savings by Season and Baseline System

Season	Baseline System	Sample Size	Electric Usage of DMSHP [kWh]	Baseline Energy Reduction	Net Energy Savings
Winter 2015	90% AFUE Furnace	98	683	4.87 MMBtu	2.54 MMBtu
	85% AFUE Furnace		683	5.16 MMBtu	2.83 MMBtu
	82% AFUE Boiler		683	4.54 MMBtu	2.21 MMBtu
	HSPF 7.7 DMSHP		683	907 kWh	224 kWh
	HSPF 8.2 DMSHP		683	851 kWh	168 kWh
	Electric Resistance		683	1,092 kWh	409 kWh
Summer 2015	EER 9.8 Window AC	114	159	213 kWh	54 kWh
	SEER 13.0 Central AC		159	288 kWh	129 kWh
	SEER 13.0 DMSHP		159	245 kWh	86 kWh
	SEER 14.5 DMSHP		159	220 kWh	61 kWh
Winter 2016	90% AFUE Furnace	60	763	6.9 MMBtu	4.3 MMBtu
	85% AFUE Furnace		763	7.31 MMBtu	4.7 MMBtu
	82% AFUE Boiler		763	6.44 MMBtu	3.83 MMBtu
	HSPF 7.7 DMSHP		763	989 kWh	226 kWh
	HSPF 8.2 DMSHP		763	929 kWh	166 kWh
	Electric Resistance		763	1,547 kWh	784 kWh

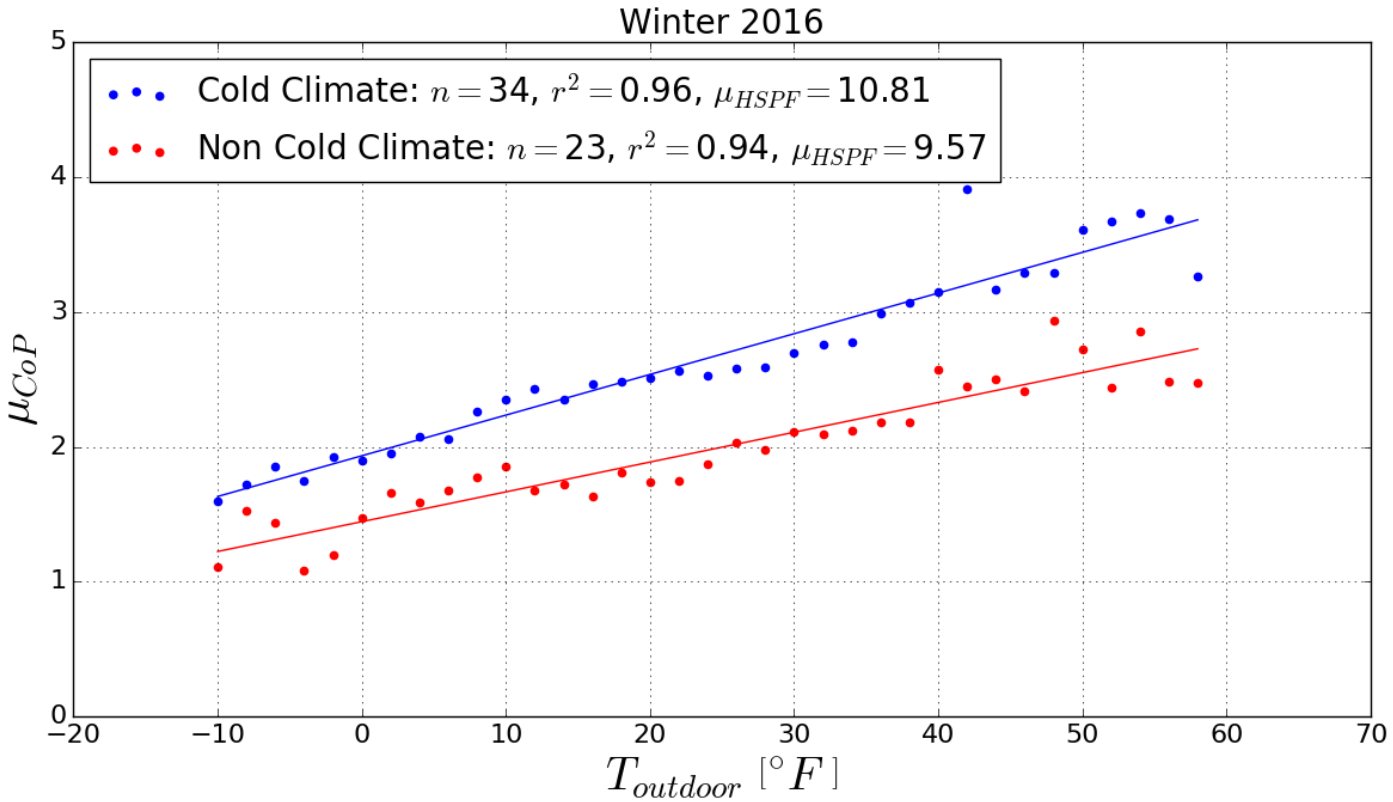
Power Savings by Season and Baseline System

Season	Baseline System	Sample Size	Electric Usage of DMSHP [kW]	Baseline Power Reduction [kW]	Average Peak Period Demand Savings [kW]
Winter 2015	90% AFUE Furnace	98	0.21	0	-0.21
	85% AFUE Furnace		0.21	0	-0.21
	82% AFUE Boiler		0.21	0	-0.21
	HSPF 7.7 DMSHP		0.21	0.28	0.07
	HSPF 8.2 DMSHP		0.21	0.26	0.05
	Electric Resistance		0.21	0.33	0.12
Summer 2015	EER 9.8 Window AC	114	0.11	0.15	0.04
	SEER 13.0 Central AC		0.11	0.20	0.09
	SEER 13.0 DMSHP		0.11	0.05	0.06
	SEER 14.5 DMSHP		0.11	0.07	0.04
Winter 2016	90% AFUE Furnace	60	0.25	0	-0.25
	85% AFUE Furnace		0.25	0	-0.25
	82% AFUE Boiler		0.25	0	-0.25
	HSPF 7.7 DMSHP		0.25	0.33	0.08
	HSPF 8.2 DMSHP		0.25	0.31	0.06
	Electric Resistance		0.25	0.58	0.33

Seasonal Efficiency vs. Season



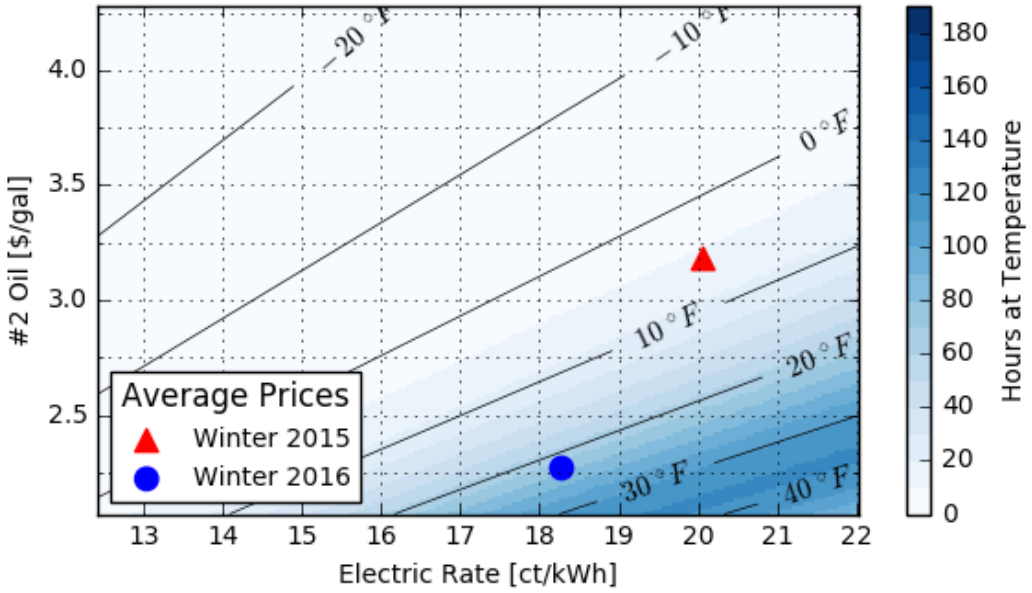
Cold Climate Performance



Average CoP vs. Outdoor Air Temperature

Trade-offs with Primary Heating Systems

- Assumed 0.8 primary system efficiency
- Average prices MA fuel and electric prices from 2015 and 2016
- Observed price ranges from past 10 years
- Web App: https://cadmus.shinyapps.io/dmshp/



Ductless Heat Pump Economic Trade-offs

Primary System Type:

#2 Oil

Primary System Efficiency:

0.8 — 0.95

0.8 0.82 0.84 0.86 0.88 0.9 0.92 0.94 0.95

Duct/Hydronic System Efficiency:

0.8 — 0.85 — 1

0.8 0.82 0.84 0.86 0.88 0.9 0.92 0.94 0.96 0.98 1

#2 Oil Rate [$/gal]:

2.1 — 2.5 — 4.3

2.1 2.32 2.54 2.76 2.98 3.2 3.42 3.64 3.86 4.08 4.3

Electric Rate [$/kWh]:

12.4 — 13.39 — 22

12.4 13.36 14.32 15.28 16.24 17.2 18.16 19.12 20.08 21.04 22

DHP Efficiency Curve:

Cold-Climate Units

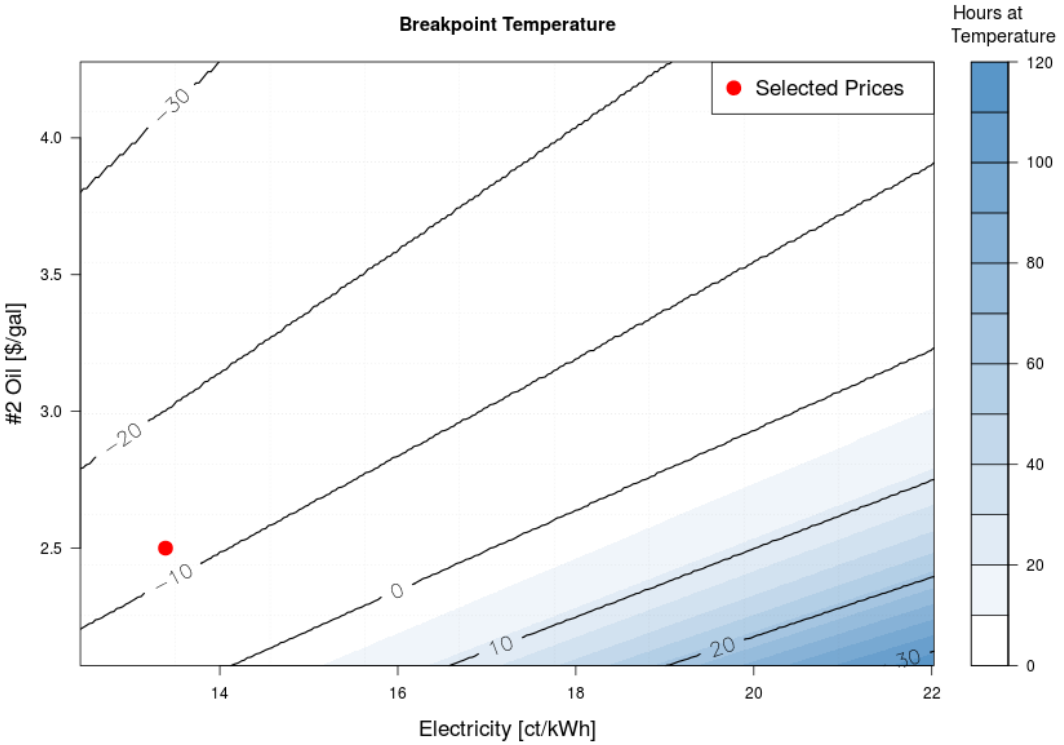
Weather Station:

Boston, MA (Logan)

Zoning Factor:

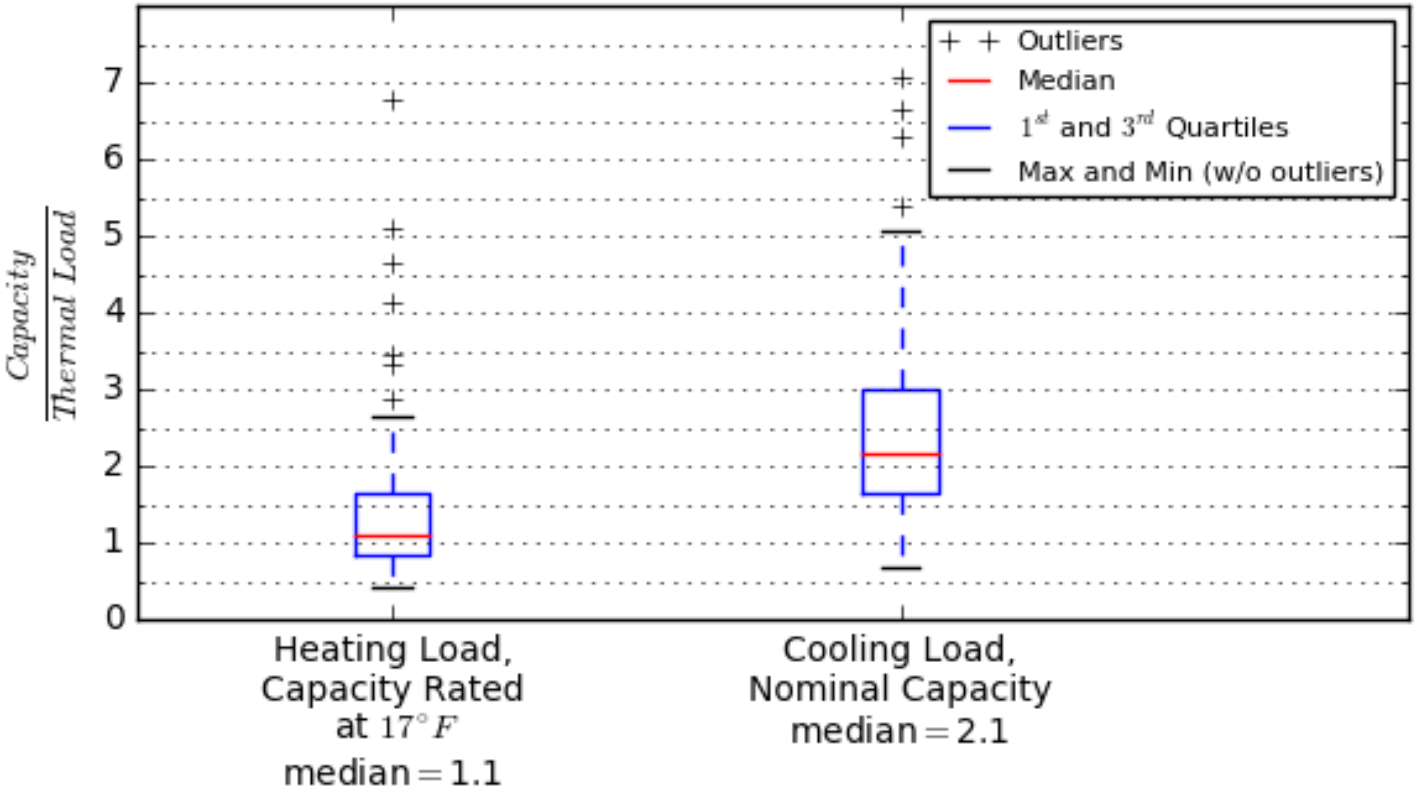
0.25 — 1

0.25 0.33 0.41 0.49 0.57 0.65 0.73 0.81 0.89 0.97 1



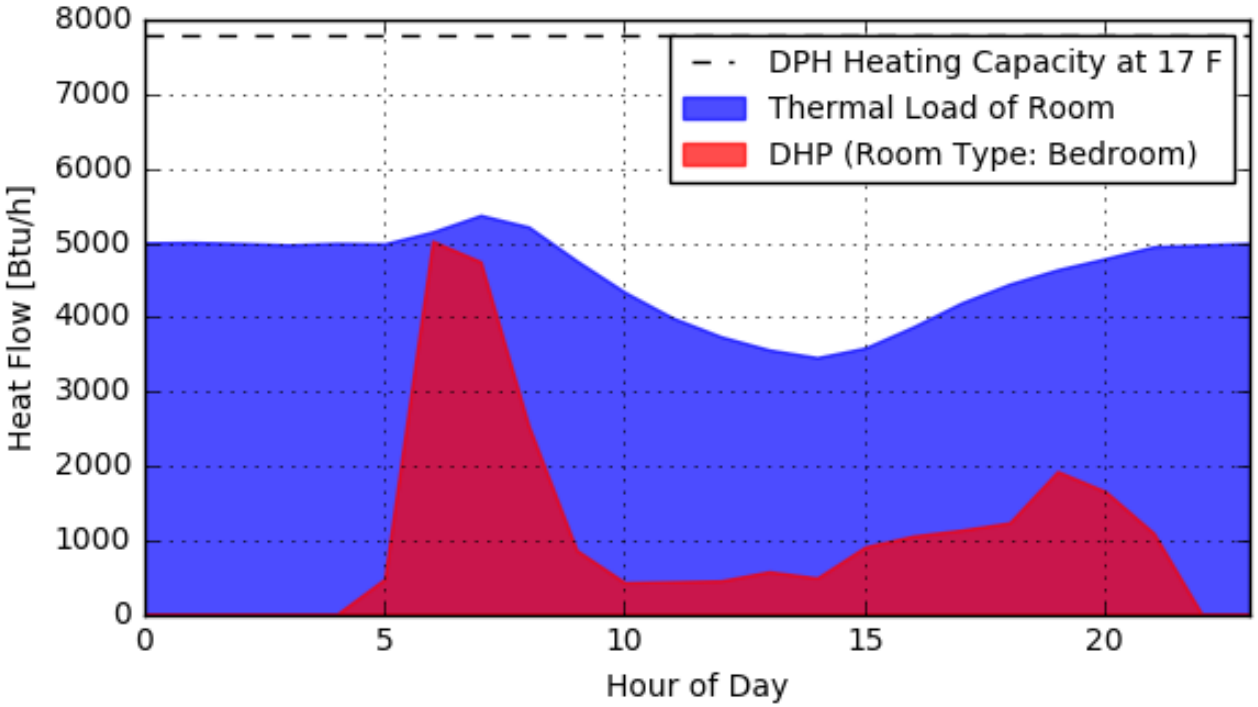



System Sizing



DHP System Capacity vs. Thermal Load of Spaces Served

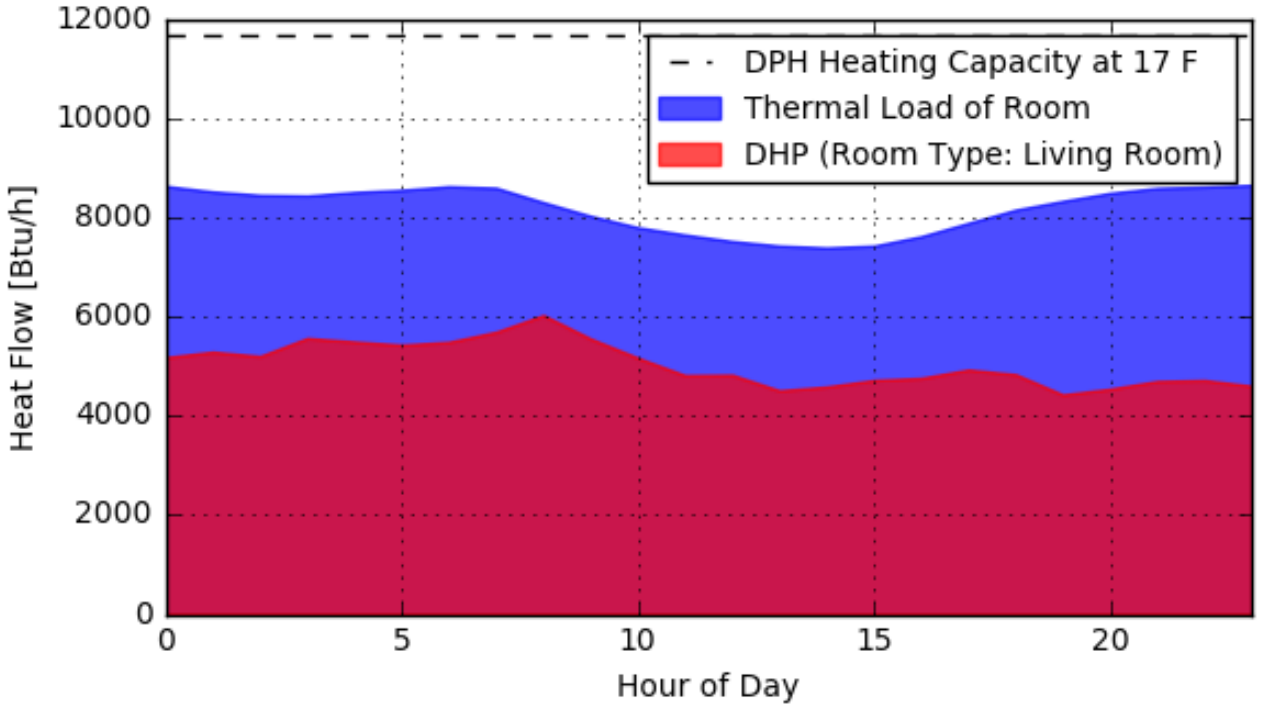
Average Daily Load to Heat Provided, Example 1



Average DHP Heat Output and Thermal Load

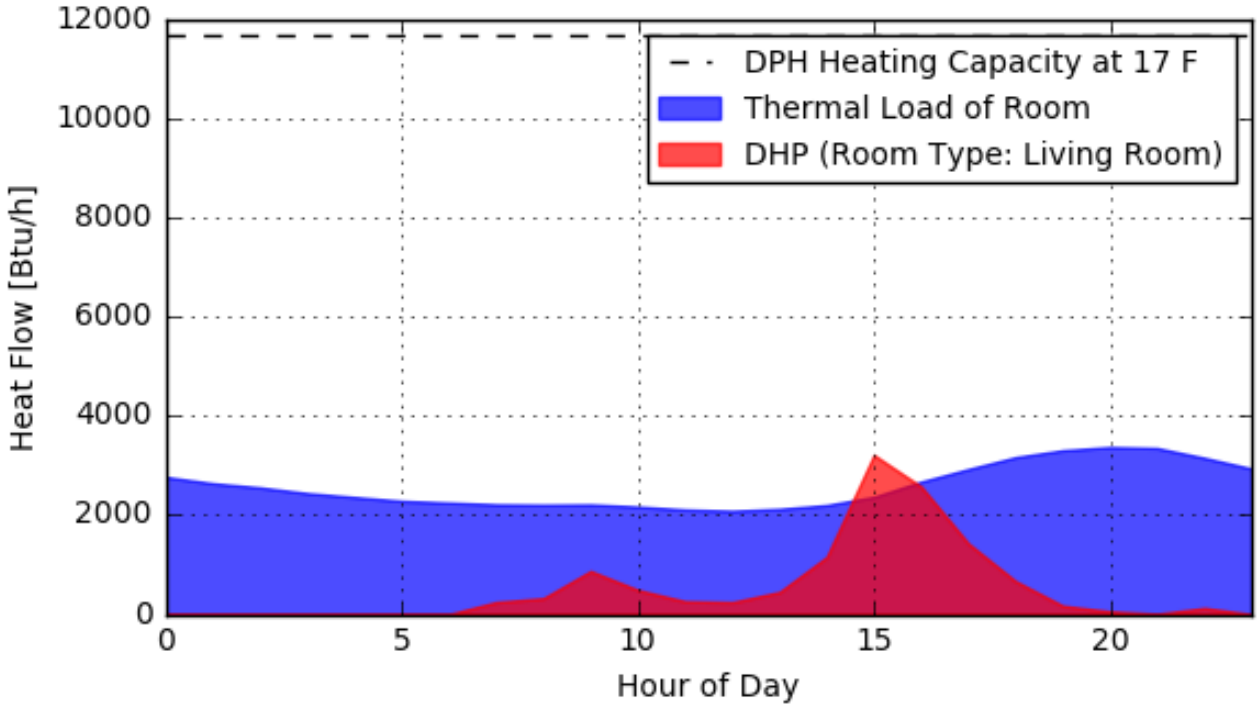



Average Daily Load to Heat Provided, Example 2



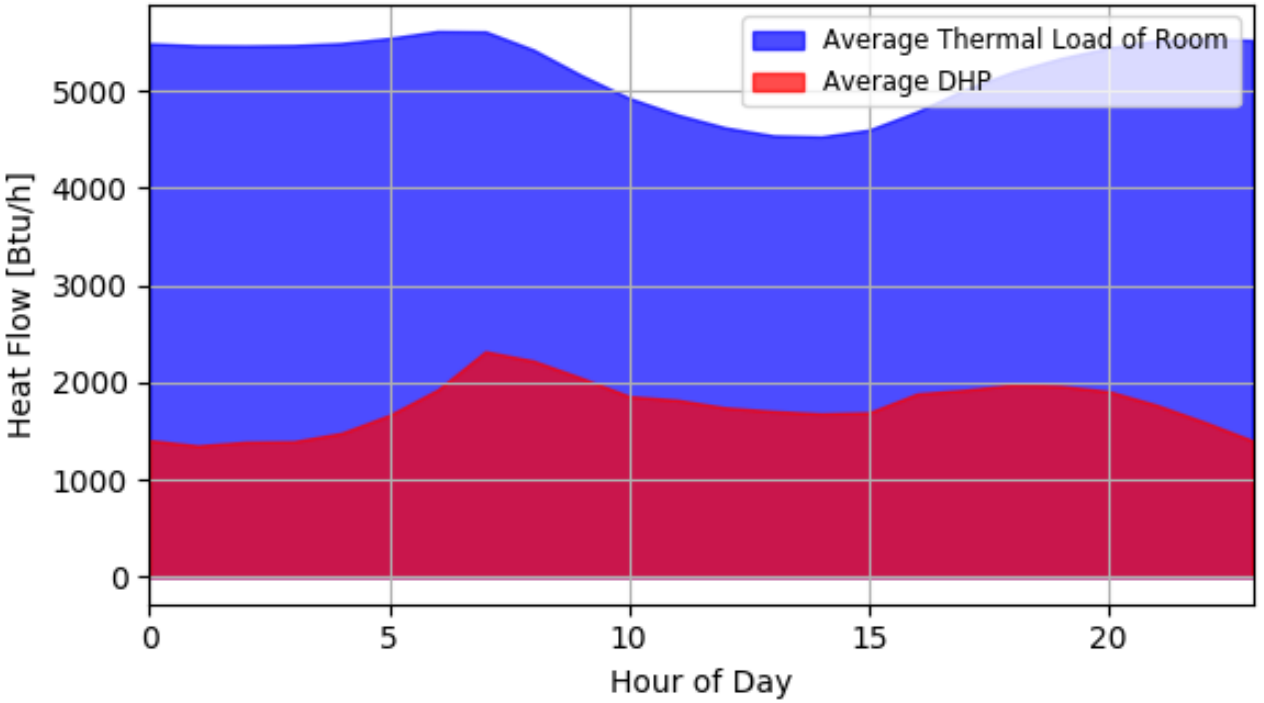
Average DHP Heat Output and Thermal Load

Average Daily Load to Heat Provided, Example 3



Average DHP Heat Output and Thermal Load

Average Daily Load to Heat Provided, N=93



Average DHP Heat Output and Thermal Load

Primary Findings

- Determine energy savings
  - Lower EFLH than previously assumed reduce TRM savings
- Compare performance of cold climate and non-cold climate systems
  - Higher performance of cold climate units correlate with HSPF ratings
- Evaluate system sizing
  - Systems sized for heating at low temperatures

Program Recommendations

- Incentivize higher efficiency systems
- Target homes heating with electric resistance or propane
- Displace central air conditioners in new construction

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